How a changing climate could alter your ground risk profile

Drier summers, wetter winters and higher-intensity storms will all impact in the ground risk that structural engineers must consider on a project, explain Rebecca Fagan-Spence and Alexander Lee.

Introduction: why structural engineers need to look below the line of the foundation

People often talk about 'setting strong foundations' for various things in life and that phrase doesn't come from nowhere. Foundations and the underlying ground are part of the structural system and, just like most aspects of the built environment, will be subject to some level of climate impact.

Climate is a defining force in Earth's system and has been impacting the planet's geology for eons. One might think that the timescale of the climate is too broad to impact the ground on an asset life-cycle level, but shifts in the frequency and intensity of rainfall can dramatically change shallow soil properties. The question is therefore not just whether a foundation has adequate capacity on the day it is designed, but whether the ground model remains credible for the design life of the asset.

Climate change is a natural process – take it from a geologist! The planet has spent millions of years heating and cooling, but the anthropogenic climate change we are currently experiencing is at an unprecedented rate.

What does a rapidly warming planet mean to the UK? Warmer and drier summers, wetter winters, as well as more extreme flooding, storm events and rising sea levels[1], all of which could cause alterations to the ground supporting your structure on the timescale of an asset's life cycle. If not properly considered, climate impacts could lead to catastrophic failure of the substructure, considerable remedial works and associated losses.

The scope of this article is deliberately broad. Ground risk is not limited to bearing capacity or settlement. It also includes slope movement affecting supports, erosion and scour removing support, groundwater altering effective stress or contaminant pathways, dust generation during construction, and drainage choices that can worsen local stability. These issues sit at the interface between structural, geotechnical, civil and environmental engineering. The thread that connects them is simple: climate can change the conditions assumed in design and impact that design's performance.

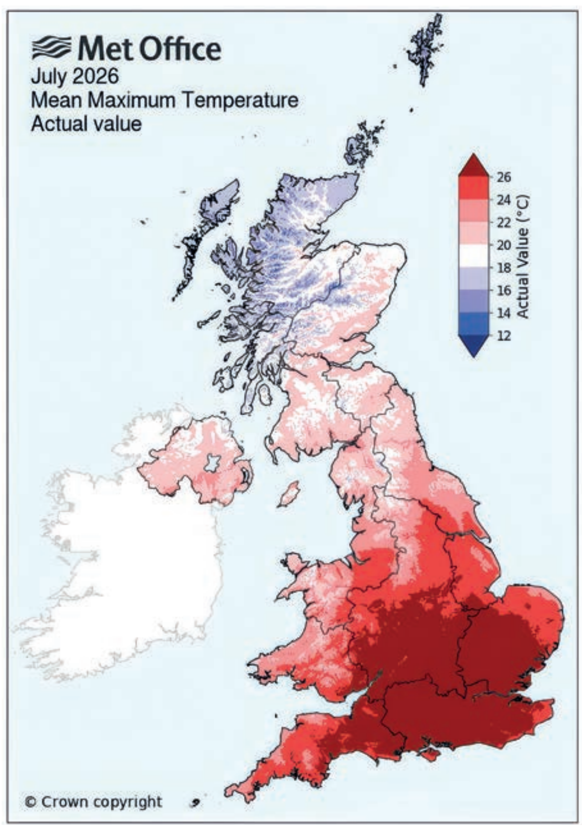

FIGURE 1: Mean maximum daily temperature in the UK, July 2026

Warmer, drier summers: shrinkage and dust

In the UK, summer 2025 was the warmest on record[2], although this looks like it will quickly be replaced in the record books by summer 2026 **(Figure 1)**. According to Met Office climate scientists, a summer as hot or hotter than 2025 is now 70 times more likely to occur as a result of anthropogenic greenhouse gas emissions than it would be in a 'natural' climate[3]. Summer 2025 was also drier **(Figure 2)**, with 84% of the long-term seasonal average rainfall usually seen across the whole of the UK[3].

Although this kind of weather will give us drier ground to lay our picnic blankets on, dry soils also hold more heat than wet soils, providing a perpetuating feedback system that could melt your ice cream faster than you can eat it. Moisture in the ground controls soil and contaminant behaviour.

Soil behaviour

Many clay soils swell when wet and shrink when dry, as well as having different soil strengths depending on their moisture content. A classic demonstration of this phenomenon is how you must add just the right amount of water to your sand to make the perfect sandcastle at the beach. If the sand is bone dry, there is too much air space between some grains and the sandcastle doesn't hold its shape; too much water and you end up with a slumped pile of wet sand; but just the right amount and you can build a perfect sandcastle that even turns out the pattern of your plastic bucket. There is also a time domain to be considered: if you leave your perfect sandcastle in the sun, the water will escape, the undrained strength is lost, and the sandcastle collapses.

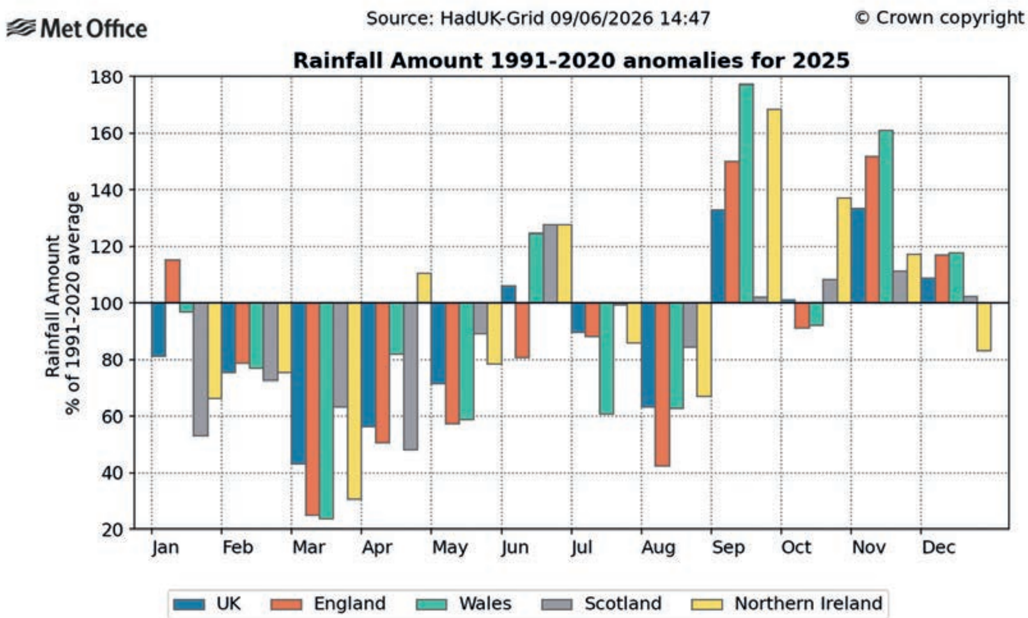

FIGURE 2: Rainfall in the UK in 2025 as percentage of 1991–2000 average

Any soil volume change or strength change can cause movements around foundations, services, slabs and retaining structures, especially where the soil is highly plastic, desiccated or influenced by vegetation. The British Geological Survey's GeoClimate Shrink–Swell work[4] combines geological mapping with climate projections to identify how susceptibility could change across Great Britain. It is a reminder that a present-day shrink–swell assessment may not be the whole story for an asset expected to remain in service into the 2050s or 2070s[5].

Imagining this concept on a larger scale, repeated wetting and drying of soils, including occasional oversaturation, particularly on slopes, can lead to deformation and failure. This is a news story repeatedly reported across the UK, especially when it disrupts transportation networks.

This isn't to say that we require deeper foundations on every site. The design team should identify whether foundation performance is sensitive to a plausible increase in seasonal soil-moisture deficit. On high-plasticity clays, this may affect founding depth or the size of tree influence zones and the detailing of movement joints or service entries. On existing buildings, it should prompt caution before adding loads, altering drainage or removing vegetation without considering how the ground moisture regime may change.

> **ANY SOIL VOLUME OR STRENGTH CHANGE CAN CAUSE MOVEMENTS AROUND FOUNDATIONS**

Contaminant behaviour

Anyone fortunate enough to visit a construction site in the British sunshine will attest to the thin layer of dust that can quite easily coat your PPE by the time you leave. As our summers get drier, this increased dustiness could mean that there is an increased inhalation of soil particulates and therefore a higher chance of you inhaling an unsuitable, or unsafe, dosage of contaminants.

Asbestos is a good example of where increased dustiness could create a significant exposure issue, as inhalation is the critical exposure pathway between source of contamination and receptor. The settling of asbestos fibres in the lungs can cause scarring and lead to asbestosis or mesothelioma. The likelihood of dust generation increases with drier working conditions, where there is minimal natural suppression of dust[6]. If soils contain asbestos and this becomes airborne due to those drier conditions, the overall risk of asbestos exposure increases, both for construction workers as well those using adjacent sites (asbestos won't respect your site boundary).

It's rarely acceptable to have asbestos present in surface soils as part of the final development, but during construction we need to be diligent about the dust generation in increasingly dry summers.

Wetter winters: slopes, retaining structures and groundwater

It was a particularly damp start to 2026 in the UK, with the Met Office reporting several of its weather stations reaching 35–40 consecutive days of rain[7]. There were a number of meteorological factors that led to this, but climate change likely played a key role. A warmer atmosphere holds on to more moisture, approximately 7% more for every degree Celsius increase in temperature[1]. All that moisture has to go somewhere. Eventually, it ends up on the ground, sometimes as puddles, sometimes in our surface-water systems, and often soaking into the ground and existing as groundwater within aquifers.

It's no secret that the UK's ageing infrastructure wasn't designed with climate change in mind; and there is an irony in the fact that our rail infrastructure was built to support the industrial revolution and is now at risk due to the consequences of releasing untold tonnes of CO_2 into the atmosphere. Climate impacts are seen in the form of landslips in cuttings and embankments when persistent rainfall saturates the slope and reduces its strength.

In addition, saturated ground no longer has the ability to act as a sponge and attenuate rainfall by absorption[8]. Instead, surface-water run-off increases, which can lead to unexpected places suffering surface-water flooding. As the surface water flows downhill, it may find its path blocked by a retaining wall; if the back-of-wall drainage is not performing adequately, the water pressure will build behind the wall, which can lead to retaining wall failure.

Where this increased rainfall does manage to infiltrate into the ground, it will find its way to a groundwater body or water table. Reduced abstraction from the industrial revolution is already causing rising groundwater tables in several of the UK's major cities (including Birmingham and Manchester[9,10]), but increased rainfall associated with climate change may exacerbate this.

Rising groundwater, as well as being a physical issue – remember, soil moisture impacts behaviour – can also mobilise contaminants that have bothered no one for decades. A small pocket of soils with a high metal concentration could become wet, with metals leaching into the water table and making their way into drinking water supplies or a nearby river. A study of light non-aqueous phase liquids (LNAPL) **(Figure 3)** remediation in the chalk aquifer by the University of Sheffield and the Environment Agency[11] showed how contaminant migration was heavily controlled by recharge events and groundwater behaviour.

Removing support: intense storms and scour

We've all seen the headlines about the increasing storm intensity across the UK. Heavy rainfall events can lead to flash flooding and significant short-term erosion. Canyon Lake Gorge in Texas, USA was carved out over a period of just a few days. In 2002, 860mm of rain fell over the upper river catchment in a single week; the subsequent massive peak flow rate of the river eroded away the rocks and soils leaving a gorge 1.5 miles long and up to 24m deep[12].

Although we haven't seen anything as extreme as Canyon Lake Gorge in the UK, as an island nation we have a significant amount of coastline at risk from climate impact. The Holderness coast in the east of England is the fastest eroding coastline in the UK, with a recorded loss of 1.8m to 2.0m of land per year (up to 2M tonnes of soil)[13]. This is largely owing to the prevalence of storms hitting the east Yorkshire coastline and oversaturating the soft, unconsolidated glacial clays that underlie the area, causing them to slump and fail. Relative sea-level rise adds a further layer of regional variation.

Around the UK, observed sea level has risen by about 20 cm since 1901 and the rate is accelerating. In southern England, glacial isostatic adjustment causes land to subside in the order of 0.5–1mm per year[14], increasing relative sea-level rise locally. This rebound combines with global sea-level rise and storm effects to increase coastal exposure for assets with long design lives.

Storm-driven coastal erosion also affects infrastructure. An instance of this was seen in Dawlish, Devon in 2014 when a particularly ferocious storm washed all the soils out from below the railway tracks, making them unsafe for use. More recently, the same line was subject to closures following scattered debris on the line following Storm Ingrid in 2026, although adjacent to a different part of the sea wall. Network Rail updated its policies in 2021 to reflect future climate change predictions, a move that will see more resilient infrastructure built and an inspection of assets deemed most at risk from these changing conditions.

↗FIGURE 3: **Light non-aqueous phase liquid recovered from borehole**

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What should you do about it as a structural engineer?

There is a lot in the above to consider. We understand some of the ways in which the climate can impact the ground beneath our structures and infrastructure, but how do we design for it? The lesson for structural engineers is to avoid treating ground parameters as immutable numbers. Ground models should identify the assumed water regime, the direction in which climate could move it, and the design elements sensitive to that change. This is particularly important where the structure is slender, movement-sensitive, founded shallowly, adjacent to a slope, supported by retaining structures, or dependent on the continued performance of buried drainage.

Carbon intensity is often something considered synonymously with climate change. There can be a unique balancing act of ensuring a design is engineered for the future while still providing an efficient and carbon-conscious solution. The factor that is often missed from this equation is the carbon cost of remedial works or, at worst, a full-scale rebuild of the asset. Building once, and building well, will almost always be more economical for finances. Reuse and adaptation of buildings is significantly lower in carbon than building new, but be warned – a reused structure may be relying on foundations or drainage details designed for a different climate baseline, a different terrain profile or a different service regime.

Ground engineers have familiarity in working within a dynamic system with a limited data set; therefore, an additional extrapolation for climate isn't the hardest to account for. The largest factor to consider when we look at potential climate impacts is uncertainty in the predictions and the precise magnitude of change we can anticipate on site. Where it isn't reasonable to predict those changes, we can look at the sensitivity of our designs to potential changes in ground conditions driven by climate effects. So, rather than trying to predict how much the water table is likely to rise by, we can consider how much it needs to rise by in order to cause our design to fail and what the potential likelihood of that occurring is. A ground engineering specialist will be a great ally on your design team.

Consideration of climate impact on the underlying soils on your site can easily become an 'out of sight, out of mind' problem, but setting a strong foundation for your development, one resilient to potential climate change, will stand you in good stead for the future, whatever it might hold.

Rebecca Fagan-Spence
MSci(Hons), CGeol, FGS

Becca is a Principal Geoenvironmental Engineer and Chartered Geologist at Cundall. With a decade of experience in land quality, Becca supports Cundall's low-carbon ethos through robust site-specific technical advice.

Alexander Lee
MSci, MSc, CEng, MICE, CGeol, FGS

Alexander is a geotechnical engineer with over 20 years' experience gained on public and private sector projects in the UK and the Middle East. He is primarily involved in ground characterisation, earthworks and geotechnical design.

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